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ABSTRACT

Reported are the results of an experiment in which twelve different conservation of length tasks, indicative of passage from Piaget's pre-operational to concrete operations stages of cognitive development, were administered to a sample of individuals from Imbonggu-speaking people, a remote and traditional society in Papua New Guinea. Individuals were systematically selected to represent four varying age levels from 7 to 20 years and four education levels from 0 to 10 years. Results are consistent with neo-Piagetian interpretations of cognitive development which see development proceeding gradually in a continuous rather than stage-like fashion, and as heavily dependent on environmental influences--in this case, English language usage associated with seven or more years of formal schooling. (MNS)

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INDIGENOUS MATHEMATICS PROJECT

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INTRA-CULTURAL VARIATION IN COGNITIVE DEVELOPMENT — CONSERVATION OF LENGTH AMONG THE IMBONGGU

David Lancy
Randall Souviney
Venina Kada

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THE INDIGENOUS MATHEMATICS PROJECT

This series of working papers and research reports has been published to provide a comprehensive source of documentation on research and development efforts associated with the Indigenous Mathematics Project. The Project was established in 1977 by the Government of Papua New Guinea to investigate various aspects of traditional mathematics development. During the first phase (1977–79) of the five year program, basic research in crosscultural cognitive development was carried out and indigenous counting, classification and measurement systems used throughout the country were documented. During the second phase of the project (jointly funded by the Department of Education and UNESCO), pilot instructional materials were developed and trialled. The intent was to assess the feasibility of utilizing complementary aspects of indigenous and Western mathematics as a basis for developing culturally relevant student materials, instructional aids and teachers' guides which reflect the practical constraints of the community school environment. The results of IMP work are intended to inform future curriculum development in an effort to provide more appropriate instructional materials and learning aids for Community Schools throughout Papua New Guinea.

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INTRA-CULTURAL VARIATION IN COGNITIVE DEVELOPMENT
CONSERVATION OF LENGTH AMONG THE IMBONGGU

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This article reports the results of an experiment in which twelve different conservation of length tasks, indicative of passage from Piaget's pre-operational to concrete operation stages of cognitive development, were administered to a sample of individuals from a remote and traditional society in Papua New Guinea. Individuals were systematically selected to represent varying age and education levels. Results are consistent with "Neo-Piagetian" interpretations of cognitive development which see development proceeding gradually in a continuous, rather than stage-like fashion, and heavily dependent on environmental influences, in this case, English language usage associated with seven or more years of formal schooling.

Intra-Cultural Variation in Cognitive Development: Conservation of Length Among the Imbonggu

The study reported here follows upon a vigorous program of cross-cultural cognitive research in Papua New Guinea (Shea 1978a) which dates back to 1968 (Kelly 1977). One characteristic of this research, in contrast to the general trend in cross-cultural psychology, is that comparisons are made across cultures within Papua New Guinea (a nation with over 700 distinct languages); the cultures compared vary in a number of ways, but all are non-Western, and pre-technological. The earlier research (Kelly 1977) demonstrated variation in the rate of achievement of concrete operations across cultures, in general, and, in several specific cases, a very low rate of achievement of conservation of length, even among teenagers. These findings have recently been successfully replicated and extended (Shea 1978b; Lancy 1978a) with the further finding that schooling, especially beyond primary grades, greatly enhances the likelihood of successful performance on a variety of cognitive tasks, conservation of length in particular.

In addition to previous research in Papua New Guinea, the present study has been influenced by studies which demonstrate that: conservation skills can be successfully trained (Beilin 1965; Gelman 1969; Brainerd 1977; Anderson & Clark 1978); very young children can demonstrate conservation skills under certain conditions (Siegel 1978); college students can be shown to fail a conservation task under certain conditions (Murray & Armstrong 1978); and conservation can be "extinguished" (Miller 1976; Robert & Charbonneau 1978). Taken together with the Papua New

Guinea research, these studies would seem to support the view that: 1) conservation is learned; 2) not all societies provide the relevant learning opportunities; 3) western-style schooling does provide such opportunities; 4) conservation is not an all-or-none concept but, rather, will be employed sparingly or widely, depending on the individual's level of "certainty" (Miller, Brownell & Zuiker 1977), and 5) certainty is strengthened with increased age and/or level of education.

Our attempt to probe these ideas involved the use of twelve different measures of conservation of length with a population of Imbonggu-speakers from the area around Ialibu in the Southern Highlands Province of Papua New Guinea, with samples taken from four age levels (7-9, 10-12, 13-15, 16-20) and four levels of education (0, 1-3, 4-6, 7-10). These samples were chosen to facilitate the testing of the relative effects of age and education on the attainment of conservation of length. Sub-samples were created to test for the effects of testing language (English vs. Imbonggu) and relative success in primary school (high vs. low achievers). Conservation of length tasks were borrowed or developed to provide a range of difficulty in order to test for the possibly gradual acquisition of conservation of length and a possible continuum from rare to frequent employment of the concept. The range of difficulty problem was attacked in three ways. First, from previous research (Shea 1978b; Lancy 1978a) two tasks were known to yield different levels of difficulty for the Imbonggu. Task A (below) has been most widely employed in Papua New Guinea, and Imbonggu children, in particular, are unlikely to give conserving responses on this task (e.g. 25% of 10-13 year olds in grades 5-6 [Lancy 1978a, p. 122]). The task used by Shea (1978b) was considerably

easier, but in this study we have broken it into its two components, namely a race (task C) over straight and curving strings of unequal length (task F). Second, tasks K and L were designed to accentuate schooling effects as they permit the application of skills, specifically taught in grades 1 to 3, to aid solution of the problem. Third, we designed tasks that used either very familiar stimuli (tasks D, G, J) or very unfamiliar stimuli (tasks H, I). Clear tubing and pulleys are unknown to these people while necklaces composed of various materials used as "beads" and digging sticks as horticultural implements are ubiquitous.

METHOD

Subjects

Imbonggu-speaking people, numbering less than 5,000, inhabit an area of uneven, medium altitude terrain between Mts. Giluwe and Ialibu in the Southern Highlands Province. The area lies about 500 km north-east of Port Moresby, the capital city and, being extremely inaccessible, was first contacted by outsiders only in the last three decades. The Imbonggu are horticulturalists, their chief crop is the sweet potato. In general, they have a great deal in common with other societies in the Central Highlands of formerly Dutch and formerly Australian New Guinea (Brown 1978). Schools and roads have been introduced during the last twenty years. Approximately 50 percent of those eligible attend primary (Community) schools, a much smaller fraction attend (Provincial) high schools. All students at all levels of schooling live at home in the surrounding villages (or hamlets) and walk to school each day. When

they are not in school, they participate fully in the normal round of village-life. Our testing was done in the Kero Community and Ialibu Provincial High schools. Individuals not attending (and who had never attended) were easily found in the vicinity of these schools to serve as "unschooled" samples.

One-hundred and five subjects were tested and assigned to age and level of education sub-groups as shown in Table 1.

Table 1

Distribution of Subjects: Sample Sizes

	Level of Education				
Age Level	0 yrs	1-3 yrs	4-6 yrs	7-10 yrs	Total
7-9 yrs	9	11	0	0	20
10-12 yrs	10	0	15	0	25
13-15 yrs	10	0	20	12	42
16-20 yrs	10	0	0	8	18
Total	39	11	35	30	105

Tasks

A. Pitpit Horizontal. The S is presented with two pieces of pitpit (a bamboo-like material indigenous to the Highlands region) equal in length (approximately 50cm). The pieces are arranged in a parallel configuration from left to right positioned with collinear ends. The S is asked to observe and touch the two pieces and is asked, "Are these two pieces of pitpit the same length or is one piece longer?" If initial agreement cannot be reached, the S is asked which is longer and a small bit is whittled off that piece by the interviewer. The subject is again queried as to equivalence and the process continued until the S is satisfied. The interviewer then moves one of the pieces in a

parallel fashion either left or right approximately 10-15cm. The S is then asked, "Are the two pieces of pitpit still the same length, or is one piece longer now?" If the S indicates that the lengths remain equivalent, justification is elicited. If the justification is logical (i.e.: They were the same before, so they are the same now, you just moved one), the S is considered concrete operational. If the S indicates that one is now longer, justification is elicited and the piece is returned to its original position. The process is now repeated only the other piece is moved. If the subject still claims one is longer, he is considered pre-operational. If he changes his mind and indicates they are now equal in length, justification is elicited and if logical, the S is scored as transitional.

B. Pitpit Vertical. Two pieces of pitpit equal in length are presented in a similar manner as A above, only the sticks are positioned across the table, pointing directly away from the S. The procedures are parallel to those in A.

C. Pig Run. The S is presented with two identical wooden rods (10cm x 1cm x 1cm). He is then told the following: "Suppose we have two pigs and we put one here (point to the end of one rod) and the other one here (point to the end of the other rod). Now suppose they start at the same time and run at the same speed. Will they both reach the end (point to the opposite ends of the rods) at the same time, or will one get there first?" If the S states that the pigs will arrive at the same time, continue as below. If not, repeat the story in more detail, modeling the pigs' movements with two pencils until the subject accepts the initial conditions. Next the rods are shifted and the story is repeated. If the subject says that the pigs will arrive at the same time, he is asked for

justification. If the response is logical (i.e.: They are both running the same distance and are starting at the same time so neither will win.), the S is classified as concrete operational.

D. Digging Stick. Two digging sticks of equal length (approximately 50cm sharpened on one end) are presented by standing them vertically in front of S on level ground. Following the establishment of identity, one of the sticks is driven into the ground (10-15cm), and S is asked, "Are the two digging sticks the same length, or is one longer now?" A S who indicates that the two sticks are still the same length and offers logical justification is classified as concrete operational.

E. Equal String. The S is presented with two pieces of string of equal length (25cm) displayed in a horizontal, parallel configuration with both ends collinear. After establishing identity, the interviewer then bends one of the strings forming a curve with one end collinear with the corresponding end of the straight string and the other positioned about two-thirds the distance along the straight string. He then asks, "Are the two strings still the same length, or is one longer now?" A S who indicates that the strings remain equal and offers logical justification is classified as concrete operational.

F. Unequal String. A procedure similar to E above is followed, except the initial condition is reversed (unequal vs. equal). The long string (25cm) is subsequently curved so that the ends are collinear with the straight string (15cm) and the S queried as to equivalence after the transformation. If the S indicates that one string is still longer and gives a logical justification, he is classified concrete operational.

G. Neck Beads. The S is presented with two parallel linear arrangements of colored rods (1cm x 1cm x various lengths). Both configurations

consist of five rods of varying length and color, but overall are equivalent in length. The interviewer then states, "Pretend these colored rods are beads. Are these two necklaces the same length or is one longer?" After the S agrees on the initial condition, E transforms the necklace closest to the S by placing the second rod at a 90° angle to the end of the first, the third at a 90° angle to the end of the second, and so on in a zig-zag pattern. E asks the S, "Are the two necklaces still the same length or is one longer now?" A S who indicates that the lengths remain the same and offers logical justification (i.e.: They both would fit around the same size neck.) is classified concrete operational.

H. Water Tube. The S is presented with a piece of plastic tubing (1cm diameter x 50cm length) along with three identical glasses. Two glasses are partially filled with colored water (10ml and 30ml) and the third is empty. In front of the S the interviewer fills the tube from a separate source of colored water using a siphoning method and deposits the contents (approximately 20ml) into the empty glass. The tube is tied with a simple overhand knot in front of the S. The interviewer asks, "Which glass would fill up the tube again with nothing left in the glass?" A S who gives the correct response (the 20ml glass) with logical justification is classified as concrete operational.

I. Pulley System. The S is presented with a device which is comprised of a red cord (20cm) strung at right angles over a pulley and the horizontal segment is connected to the support bracket by a rubber band. A weight pan is attached to the end of the vertical segment of the cord.

By putting a 500 gram weight on the pan, the rubber band stretches, allowing the string to run through the pulley about 5cm lengthening the vertical segment while shortening the horizontal segment. The S is asked, "If I put this weight on the pan here (place the mass piece on the pan), does the red cord stay the same length or does it get longer or shorter?" The S who answers the question correctly ("same") and offers logical justification is classified as concrete operational.

J. Arms. The S is asked to place his elbows on the table in front of him, with his forearms together, palms up. The interviewer asks, "Are your two arms from here (pointing to one elbow) to here (pointing to the tip of the fingers of the same arm) and from here to here (same procedure), the same length, or is one longer?" After the S agrees with the initial condition, E moves one arm up, parallel to the other approximately 15cm. He asks the S, "Are your two arms from here to here (pointing), and from here to here (pointing) the same length, or is one longer now?" The subject who answers correctly and offers logical justification is classified as concrete operational.

K. Brown Rods. The subject is presented with a brown Cuisenaire rod (8 units long) and 14 unit cubes. The S is asked, "How many of these little blocks will exactly fit along the edge of this brown rod?" The S is encouraged to physically manipulate the blocks. Once the S has determined that eight unit blocks are equivalent to the brown rod (perhaps with the assistance of the interviewer), a second brown rod is produced and the standard length transformation procedures (A) are employed (rods remain touching). If the S fails to conserve, the

interviewer asks, "How many little cubes does it take to make up this brown rod (point to one rod)? And this one?" The subject may need assistance recounting the units or may need to remanipulate the blocks. After the S agrees that each brown rod is equivalent to 8 units, the standard length transformation procedure is repeated. A S who conserves after the first transformation procedure is classified as concrete operational and the procedure stops. For others, guided measuring takes place as above followed by a repetition of the transformation and question. If the S is successful on the second attempt, he is classified as transitional. If neither attempt is successful, the S is considered pre-operational.

L. Ten Rods. The subject is presented with one unit cube and a scored ten rod. The S is asked, "How many of those little blocks would fit along this long rod?" Once it has been established that ten unit cubes are equivalent to one rod, a second ten rod is produced and the procedure as in K above is followed.

For those tasks where the transitional stage is not defined in the protocol, the interviewer applies this classification when, during the justification stage, the S seems unsure of his answer and when probed, changes his mind one or more times.

Procedure

The tasks were conducted in the Imbonggu language for the majority of subjects. Instructions were refined by translations from English into Imbonggu back to English, and then into Imbonggu for the basic

terminology. However, the procedure was, in general, clinical. S's were tested individually in a spare room at schools (Kero Community School, Ialibu High School) by a local interpreter, a Papua New Guinea experimenter and an expatriate supervisor. Neither interpreter nor experimenter were aware of the hypotheses under examination. Tasks were re-explained and repeated as often as necessary to assure that S's fully understood what was required, there were no time constraints. Each S was given each task administered in a random order, and the conservation of length tasks were interspersed with a distractor task where the S was asked to copy a model figure laid out on a geo-board on his/her own geo-board.

All high school S's requested that they be tested in English. 15 S's non-systematically selected from grades 4-6 were also tested in English, later to be compared to 20 same age class mates who were tested in Imbonggu to check for possible facilitative effects of English which had been found in earlier research with similar S's (Kelly 1977). Since only the top 30% or so of Community School graduates are selected for high school, level of education beyond grade six is confounded with achievement level. Unable to control for this effect, we sought to measure its impact by asking teachers to decide who, among our 35 S's in grades 4-6, was extremely likely (high achievement) to be selected for high school, and who was extremely unlikely (low achievement) to be selected. The teachers were able to make such an assignment for 29 of our S's, 16 being assigned to a high achievement group, 13 to a low achieving group, later to be compared for possible achievement effects and thereby determine whether the substantially

improved performance of Imbonggu high school students as compared to primary-school students found previously (Lancy 1978a) could be dismissed as a selection artifact.

Finally, note that in scoring, we were interested in assessing the performance of individual S's over all the tasks and, to this end, assigned a score of zero on each task in which the S was judged to be pre-operational, a one on tasks where the S gave a transitional response and a two for fully operational responses. These scores were then totalled, yielding a range of subject scores from zero (pre-operational on all 12 tasks) to twenty-four (concrete operational on all 12 tasks).

RESULTS

As we expected, success varied greatly over tasks and over groups. There was no improvement over tasks within S's. Success was no more likely on the tasks presented at the end of the testing period than on those presented at the beginning of the session.

The variation in difficulty levels that we had hoped to find was confirmed (Table 2). Tasks J, D, C, E, B, F (in that order) were subjected to a Gutman scale analysis which yielded a coefficient of scalability of .602. Undoubtedly, further refinement of this initial set of tasks will strengthen the conviction that individuals cannot be considered unequivocably as "conservers" or "non-conservers," rather a conserving response depends, at least in part, on the nature of the task. Our naive notions of what kind of tasks might be considered easy or hard received a set-back, however. Tasks that provided highly familiar stimuli were among the most difficult (D, J), while at least one of the

tasks that used unfamiliar stimuli was relatively easy (H).

Table 2

Performance Across Tasks as Percent

For Entire Sample (For Unschooled Subjects)

Tasks	Fail	Trans.	Conserve
Water-tube (H)	32.4 (30.8)	0 (0.0)	67.6 (69.2)
Unequal Strings (F)	41.9 (53.8)	8.6 (12.8)	49.5 (33.3)
Pit-Pit Vert. (b)	57.1 (71.8)	15.2 (12.8)	27.6 (15.4)
Equal Strings (E)	62.9 (87.2)	15.2 (5.1)	21.9 (7.7)
Pit-Pit Horiz. (A)	63.8 (76.9)	8.6 (7.7)	27.6 (15.4)
Neck-beads (G)	66.7 (87.2)	6.7 (5.1)	26.7 (7.7)
Ten Rods (L)	67.6 (71.8)	9.5 (5.1)	22.9 (23.1)
Pulley (I)	68.6 (79.5)	1.0 (0.0)	30.5 (20.5)
Pig-Run (C)	68.6 (87.2)	2.9 (0.0)	28.6 (12.8)
Brown Rods (K)	76.2 (97.4)	1.0 (0.0)	22.9 (2.6)
Dig Sticks (D)	77.1 (97.4)	1.9 (0.0)	21.0 (2.6)
Arms (J)	80.0 (97.4)	1.9 (0.0)	18.1 (2.6)

Tasks which were designed to favor school-children (K, L) did not do so: 18% of children aged 7-15 in grades 1-6 (N = 46) gave fully conserving responses on these tasks, versus 14% for 7-15 year olds not in school (N = 29). The "unequal string" procedure was indeed much easier than the "pit-pit horizontal" procedure, as we had been led to expect from previous research. Unfortunately, further research will be necessary before we can begin to unravel what underlies task difficulty for the Imbonggu. At least, relative levels of difficulty are not

markedly different for S's who have not attended school (Table 2, comparison of figures in parentheses to adjacent figures), indicating that the tasks are not systematically biased to favor more schooled individuals.

Table 3 presents a breakdown of the results for total score over all twelve problems for the various age and education sub-groups. Main effects for age ($F = 4.35$, $p < .006$) and education level ($F = 14.39$, $p < .0001$) are significant as is the interaction ($F = 4.10$, $p < .02$) reflecting the fact that students attending high school are much more likely to make conserving responses than either primary-grade children or individuals who have not attended school. Further, we find that the pupils who are likely to be selected for high school are no more proficient than pupils who are unlikely to be selected ($F = 2.13$, NS) which would indicate that the superior performance of high school students cannot be accounted for

Table 3

Mean Score Over Twelve Problems

	Level of Education				
Age Level	0 yrs	1-3 yrs	4-6 yrs	7-10 yrs	Grand Means
7-9 yrs	1.4	7.5	-	-	4.8
10-12 yrs	4.1	-	4.1	-	4.1
13-15 yrs	8.2	-	9.2	14.3	10.4
16-20 yrs	4.9	-	-	19.9	11.6
Grand Means	6.0	7.5	7.0	16.5	8.0

by their higher achievement levels in school-based skills alone. Consistent with the view that there are no such individuals as conservers and non-conservers, we find only 7.6% of the sample with a total score

of zero or completely non-conserving and only 3.8% with a score of 24, completely conserving. Finally, we note that presenting the task in English slightly enhances the likelihood of making a conserving response ($F = 4.55$, $p < .05$).

DISCUSSION

If a dichotomy must be made, it is apparent that Imbonggu who have not attended school do not achieve conservation of length. We are clearly dealing with a performance rather than a competence deficit (Greenfield 1976), because it is inconceivable that the Imbonggu, all of whom have had extensive experience working with a digging stick, actually think that the stick gets shorter as it is driven into the ground, and because high-school students, racially and culturally identical to the non-conservers, very obviously do conserve length.

What differentiates these two groups must lie in the absence of certain kinds of experiences in the village and their presence in school. There are at least three experiential factors which may be implicated. First, following Piaget (1970), it may be that the relative opportunities for "construction" or manipulative activities are different in the two cases. It is certainly true that the man-made environment in Imbonggu culture is sparse. There are only four "tools" which are used with any frequency in the society: the digging stick, the ax, the bow and arrow, and the net bag. The most elaborate and complex construction activity is employed in creating ornaments for and painting the body in preparation for exchange ceremonies which are held rarely. The Imbonggu material inventory is sparse even by comparison with other pre-technological societies in Papua New Guinea. At the same time, schools--especially high schools--are filled with varied and new materials which are manipulated

in a variety of ways, although not often in the free-ranging, discovery-oriented fashion that Piaget and his followers argue is necessary for progress in cognitive development to occur (Brainerd 1978).

A second factor might be the differential emphasis on particularistic versus generalized approaches to problem-solving in the village and the school. A review of schooling effects on cognitive skills makes the point that:

> Unschooled populations tended to treat learning and memory problems as if they were discrete experiences, each constituting a new problem. . . . Schooled groups, by contrast, . . . treat classes of problems as instances of the same type, applying common operations in appropriate ways (Cole, Sharp & Lave 1976, p. 227).

The experimental results aside, we have no evidence from ethnographic research in the village and school settings to support or deny this theory.

A third and perhaps compelling factor may be the differential structure and use of language in the two settings. Elsewhere (Lancy 1978b; Lancy & Strathern Note 1) the varying degree of hierarchicalization in Papua New Guinea's languages has been described and related to the individual's approach to various cognitive tasks. In essence, Imbonggu, like a number of other Highland's languages, lacks well-defined category or concept-level terms. Further, there is a paucity of relational terminology (terms heavily implicated in successful performance on Piagetian tasks [Siegel 1978]). The language of instruction in Papua New Guinea schools is English, a language with a rich category and relational term inventory. However, Imbonggu pupils develop fluency in the use of English very gradually and one qualitative change we have noticed is that it is only in high school that students begin using

English freely in conversation and in informal school and out-of-school settings, generally. It is probably that Imbonggu students in the primary grades cannot fully capitalize on their knowledge of English because they are still operating with Imbonggu syntactic rules (Volter & Taeschner 1978).

Notes

1. Lancy, D. F. & Strathern, A. J. "Making Twos:" Pairing as an alternative to the taxonomic mode of representation. Unpublished ms.

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